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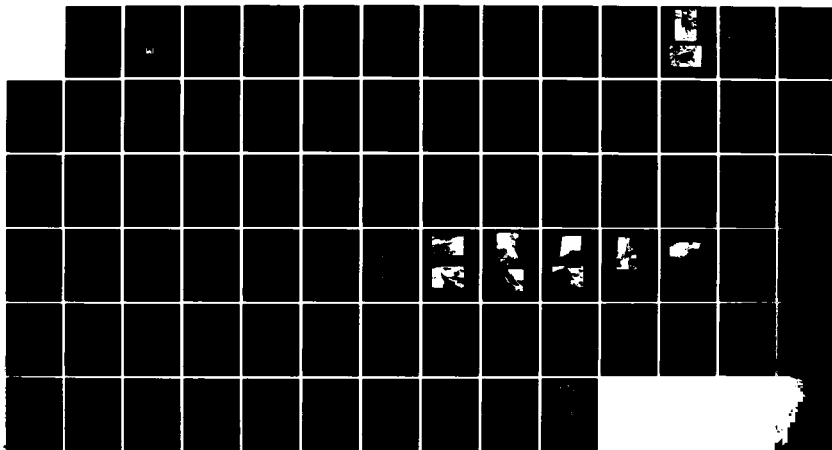
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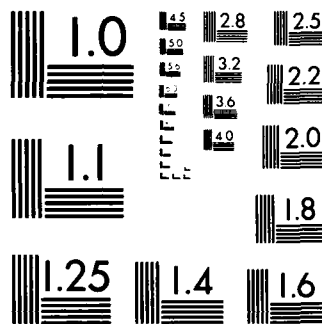
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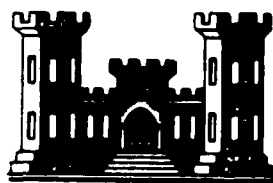
MERRIMACK RIVER BASIN  
WILTON, NEW HAMPSHIRE

AD-A156 453

HILLSBOROUGH MILLS DAM

N H 00258  
NHWRB 254.01

PHASE I INSPECTION REPORT  
NATIONAL DAM INSPECTION PROGRAM



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JUL 09 1985  
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DEPARTMENT OF THE ARMY  
NEW ENGLAND DIVISION, CORPS OF ENGINEERS  
WALTHAM, MASS. 02154

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NH 00258	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Hillsborough Mills Dam NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS		5. TYPE OF REPORT & PERIOD COVERED INSPECTION REPORT
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) U.S. ARMY CORPS OF ENGINEERS NEW ENGLAND DIVISION		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS DEPT. OF THE ARMY, CORPS OF ENGINEERS NEW ENGLAND DIVISION, NEDED 424 TRAPELO ROAD, WALTHAM, MA. 02254		12. REPORT DATE April 1979
		13. NUMBER OF PAGES 65
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report)  UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)  APPROVAL FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Cover program reads: Phase I Inspection Report, National Dam Inspection Program; however, the official title of the program is: National Program for Inspection of Non-Federal Dams; use cover date for date of report.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) DAMS, INSPECTION, DAM SAFETY,  Merrimack River Basin Wilton, New Hampshire Souhegan River		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)  The dam is a concrete and stone masonry gravity dam with an overall length of about 200 ft. The dam is 23 ft. high. The dam is small in size with a low hazard potential. The test flood flow at the dam is taken as the 100 yr. flood. The dam is in poor condition at the present time. It is recommended that a registered professional engineer be retained by the owner to perform additional studies.--		

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MERRIMACK RIVER BASIN  
WILTON, NEW HAMPSHIRE

PHASE I INSPECTION REPORT  
NATIONAL DAM INSPECTION PROGRAM

## NATIONAL DAM INSPECTION PROGRAM

### PHASE I REPORT

Identification No.: NH 00258  
NHWRB No.: 254.01  
Name of Dam: HILLSBOROUGH MILLS DAM  
Town: Wilton  
County and State: Hillsborough County, New Hampshire  
River: Souhegan River  
Date of Inspection: November 8, 1978

### BRIEF ASSESSMENT

The Hillsborough Mills Dam is a concrete and stone masonry gravity dam with an overall length of about 200 feet. The dam is 23 feet high. The spillway is 128 feet long and 14 feet high. The gate leading to the canal is operable but is not used since no power is generated at the downstream mill. The sluice gate in the left end of the spillway is operable, but there is no established operating procedure and is commonly silted or otherwise blocked.

The dam, which lies on the Souhegan River in Wilton, N.H. was once used to supply power to downstream mills. Power was generated as recently as 1977. The drainage area is 97 square miles of forested and hilly terrain. The dam's maximum impoundment of 70 acre-feet and height of 23 feet place the dam in the SMALL size category. In the event of a dam failure, the resulting property damage is not considered significant, and no loss of life would be expected. A LOW hazard potential classification is therefore warranted.

Based on the size and hazard potential classifications, and in accordance with the Corps' of Engineers guidelines the Test Flood would be between the 50 and 100-year floods. Since the hazard potential is on the high side of the LOW category, the Test Flood flow at the dam is taken as the 100-year flood.

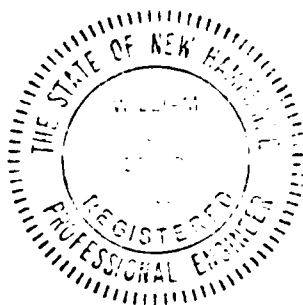
The selected TF inflow of 7750 cfs is also taken as the flow at the dam because of the small storage at the dam. The peak test discharge with no flashboards in place would result in a stage 6.8 feet above the spillway crest or 2.2 feet below the top of the dam. However, it would create 2.8 feet depth of flow around the gate house at the left abutment.

Hillsborough Mills Dam is in POOR condition at the present time. It is recommended that a registered professional engineer be retained by the owner to perform additional studies. These

studies should include the investigation of the possible settlement of the spillway, investigation of the undermining of the spillway toe, investigation of raising the low portion of the dam at the left bank, investigation of the cause of the destruction of the concrete apron, preparation of stability calculations for the dam, and investigation of settlement and seepage through the left downstream training wall. Remedial measures recommended as a result of these studies should be implemented.

The remaining flashboards on the dam should be removed immediately and should not be replaced until all remedial measures have been completed. Recommended remedial measures to be performed within one year include repair of all vertical and horizontal construction joints in the spillway, repair all spalled and eroded concrete on the various structures, and institution of a program of annual technical inspections.

The recommendations and improvements outlined herein should be implemented within one year of receipt of this report by the owner.



*William S. Zoine*  
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N.H. Registration 3226



*Nicholas A. Campagna, Jr.*  
Nicholas A. Campagna, Jr.  
California Registration 21006



## PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams for Phase I Investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the Test Flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the Test Flood should not be interpreted as necessarily posing a highly inadequate condition. The Test Flood provides a measure of relative spillway capacity and serves as an aid in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

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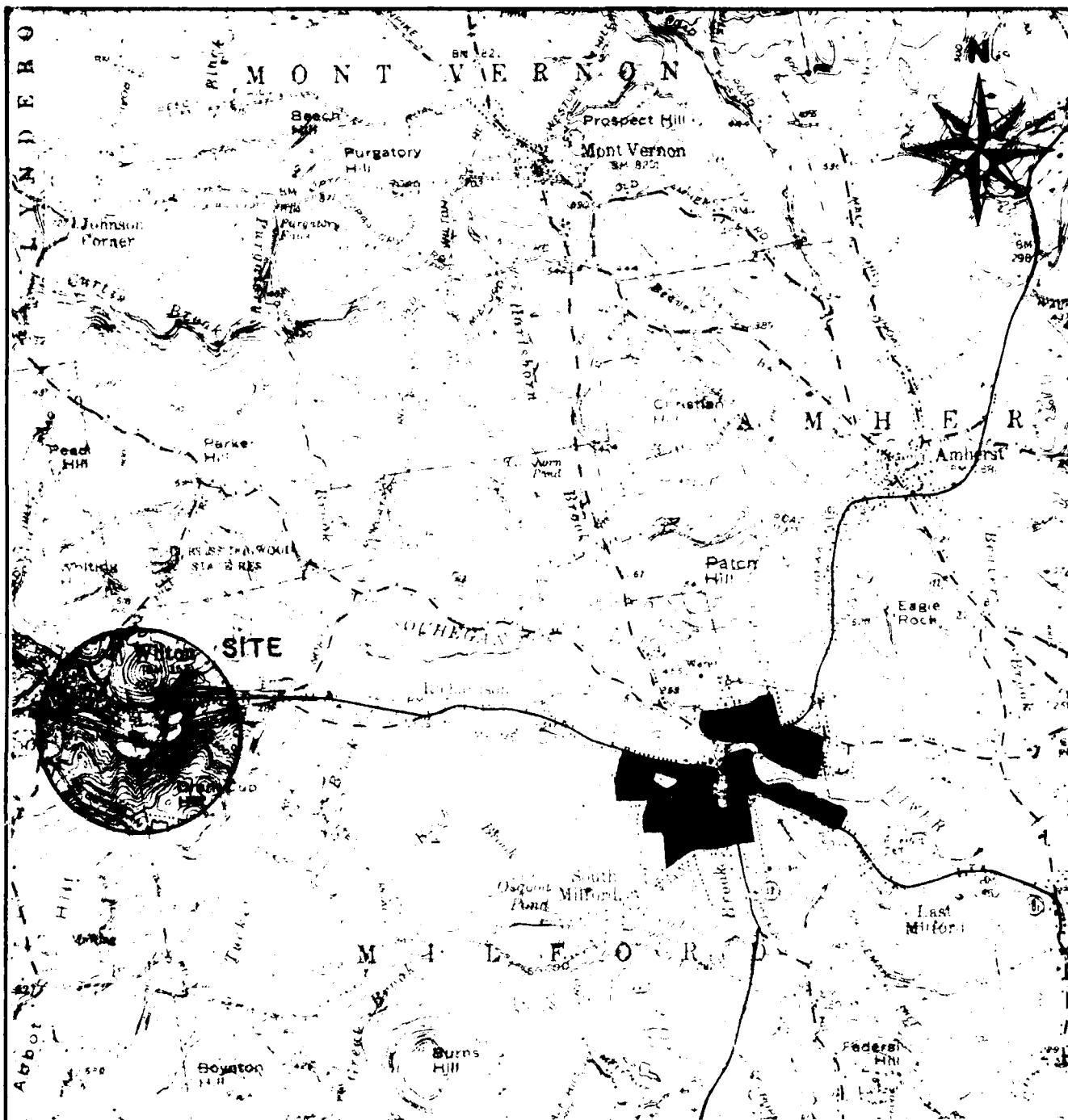
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Overview from right abutment



Overview from right side of downstream  
channel showing spillway and gatehouse



— SCALE —



FROM: USGS MILFORD, N.H.  
QUADRANGLE MAP

GOLDBERG, ZOINO, DUNNCLIFF & ASSOC., INC.  
GEOTECHNICAL CONSULTANTS  
NEWTON UPPER FALLS, MASS.

U.S. ARMY ENGINEER DIV NEW ENGLAND  
CORPS OF ENGINEERS  
WALTHAM, MASS.

NATIONAL PROGRAM OF INSPECTION OF NON-FED DAMS

## LOCUS PLAN

HILLSBOROUGH MILLS DAM

NEW HAMPSHIRE

SCALE AS NOTED

DATE

FILE No. 2201

# PHASE I INSPECTION REPORT

## HILLSBOROUGH MILLS DAM

### SECTION 1

#### PROJECT INFORMATION

##### 1.1 General

###### (a) Authority

Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a national program of dam inspection throughout the United States. The New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region. Goldberg, Zoino, Dunncliff & Associates, Inc. (GZD) has been retained by the New England Division to inspect and report on selected dams in the State of New Hampshire. Authorization and notice to proceed was issued to GZD under a letter of November 28, 1978 from Colonel Max B. Scheider, Corps of Engineers. Contract No. DACW 33-79-C-0013 has been assigned by the Corps of Engineers for this work.

###### (b) Purpose

(1) Perform technical inspection and evaluation of non-federal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by non-federal interests.

(2) Encourage and prepare the states to initiate quickly effective dam safety programs for non-federal dams.

(3) Update, verify, and complete the National Inventory of Dams.

###### (c) Scope

The program provides for the inspection of non-federal dams in the high hazard potential category based upon location of the dams and those dams in the significant hazard potential category believed to represent an immediate danger based on condition of the dam.

## 1.2 Description of Project

### (a) Location

Hillsborough Mills Dam lies on the Souhegan River in Wilton, N.H. The dam is located approximately 0.7 miles downstream from the confluence of the Souhegan River and Stony Brook in Wilton and is about 100 feet north of N.H. Route 101 at this location. The portion of the USGS Milford, N.H. quadrangle presented previously shows this locus. Figure 1 of Appendix B presents a detail of the site developed from the inspection visit and the map.

### (b) Description of Dam and Appurtenances

The dam is a concrete gravity dam with some stone masonry sections. The overall length of the dam is about 200 feet and the concrete ogee spillway is about 128 feet long. The dam also has training walls on the right and left sides, an end wall on the right side, a cut-off wall on the right side, and a gate house with a canal on the left side. There is one operable sluice gate and one sealed sluiceway in the spillway.

#### (1) Right Abutment Structure

This structure consists of a cyclopean concrete upstream training wall, a concrete cut-off wall extending into the right bank, and a gunite faced stone masonry downstream training wall. The training walls are approximately normal to the spillway axis, and the stone masonry wall has been capped with cyclopean concrete.

#### (2) Spillway

The concrete ogee spillway is about 128 feet long and 12 feet high. Two waste gates are in the spillway as is a pressure relief drain. Available plans indicate that a timber sheet pile cut-off wall was constructed at the heel of the structure. The remains of a concrete apron, which was constructed as an extension to the downstream toe of the structure, are located in the downstream channel.

An operable horizontal sliding steel waste gate approximately 4 feet wide and 6 feet high is located approximately 5 feet from the left abutment. Operation of

this gate is with a 3 foot, 8 inch diameter hand wheel located within the adjacent gate house.

An ungated sluice opening approximately 3 feet square is located approximately 3 feet from the right end of the spillway. This opening has been sealed.

The pressure relief drain is located approximately 40 feet from the left end of the spillway.

(3) Left Spillway End Structure

This structure (Photo 2) is approximately 5.5 feet wide and 10 feet long and is constructed of squared stone masonry. The stone masonry has been faced with gunite and has a cyclopean concrete cap that is about 5 feet high. The structure extends approximately 6 feet upstream from the spillway crest. The top of the wall slopes downward from the spillway axis at approximately a 2 horizontal to 1 vertical slope. The downstream training wall ties into the spillway end wall and extends downstream for about 40 feet. Approximately a 25 foot section of wall nearest the spillway is faced with gunite. The remaining portion of the wall is constructed of random dry stone masonry.

(4) Left Upstream Training Wall

This wall is about 25 feet long and is located at the upstream end of the gate house. The downstream end of this wall is also the foundation for the gate house. The wall skews upstream into the left bank.

(5) Gate House

This is a wood framed structure that is located on the left bank. The structure is about 42 feet long and 28 feet wide. The roof is supported by a timber truss upstream, and the walls are metal clad. An opening, approximately 27 feet long, is located on the right side of the building. Vertical steel trash racks are installed over the entire length of the opening from at least 4 feet below spillway crest level to the building sill.

The structure houses an electrically operated sluice gate. The timber gate is 8 feet wide, but its height could not be determined. The outlet through the building is a reinforced concrete elliptical conduit 9' x 4" wide and 7' 5" high. The conduit



connects to a dry stone masonry walled flume.

(c) Size Classification

The dam's maximum impoundment of 70 acre-feet and height of 23 feet place the dam in the SMALL size category as defined by the "Recommended Guidelines."

(d) Hazard Potential Classification

The hazard potential classification for this dam is LOW. This is because that the dam failure outflow (in the event a failure should occur) will not affect downstream structures unless the river is already at high flood stages. Under these conditions, a dam failure would add an insignificant increment to the flood level.

(e) Ownership

The dam is owned by Hillsborough Mills Company of Wilton, N.H. Mrs. Mary Abbot is an officer of the firm and can be reached by telephone at 603-654-6659. The listed telephone number for Hillsborough Mills is 603-654-2951.

(f) Operator

At present no operation is performed at the dam. Mrs. Abbot is presently overseeing the dam and its operation.

(g) Purpose of Dam

The dam was originally constructed to provide power to a mill located downstream from the dam. The water was diverted at the gate house into a canal leading to the mill. No power is generated at the site, but the gate at the gate house is still operable.

(h) Design and Construction History

According to available records the dam was built in 1912 to supply power to the downstream mill. Apparently, the concrete apron, which is now destroyed, was added to at a later date but when this work was done, is not known. The last power generation was in 1977.

(i) Normal Operating Procedure

The dam is not operated.

1.3 Pertinent Data

(a) Drainage Area

The drainage area for Hillsborough Mills Dam is 97 square miles and is predominantly forested, hilly terrain with narrow drainage channels. However, there are numerous ponds, reservoirs, and wetland areas which tend to detain run-off and thus reduce peak flows. In particular, the Soil Conservation Service (SCS) has constructed 13 flood control dams in this watershed which are designed to reduce flood peaks in the Souhegan River. These dams control 50.6 square miles of drainage area.

(b) Discharge at Damsite

(1) The two outlet works at the site are the gate which controls the flow into the downstream canal leading to the Hillsborough Mill and the sluiceway in the spillway which is operated by a sliding horizontal gate. The sluiceway outlet is about 4 feet wide by 6 feet high. The ungated sluiceway is approximately 3 feet square and is sealed.

(2) The maximum known flood at the site occurred in 1938 when the owners filled out a questionnaire stating that the water level was approximately 8.5 feet above the spillway crest. This corresponds to a flow of about 11,000 cfs.

(3) The spillway capacity with no flashboards and water level to the top of dam elevation 330 is 11,400 cfs.

(4) The spillway capacity with no flashboards and water at test flood elevation 327.9 is 7600 cfs.

(5) Spillway capacity with flashboard at normal pond elevation - Not applicable

(6) The spillway capacity with flashboards to Elevation 325 and water at test flood elevation 327.9 is 2200 cfs.

(7) The total spillway capacity at test flood condition is the same as (4) above (7,600 cfs).

(8) The total project discharge at test flood elevation 327.9 is 7750 cfs.

(c) Elevation (ft. above MSL)

- (1) Streambed at centerline of dam: 307  $\pm$
- (2) Maximum tailwater: Unknown
- (3) Upstream portal invert diversion tunnel: Not applicable
- (4) Recreation pool: Not applicable
- (5) Full flood control pool: Not applicable
- (6) Spillway crest (gated): 325 (top of flashboards)
- (7) Design surcharge (original design) Unknown
- (8) Top Dam: 330 (top of RR embankment at left side)  
325 (lowest ground at left side)
- (9) Test flood design surcharge: 327.9

(d) Reservoir

- (1) Length of maximum pool: 2000 ft.  $\pm$
- (2) Length of normal pool: 1500 feet  $\pm$
- (3) Length of flood control pool: Not applicable

(e) Storage (acre-feet)

- (1) Normal pool: 30  $\pm$
- (2) Flood control pool: Not applicable
- (3) Spillway crest pool: 30  $\pm$
- (4) Top of dam: 70  $\pm$
- (5) Test flood pool: 60  $\pm$

(f) Reservoir Surface (acres)

- (1) Recreation pool: Not applicable
- (2) Flood-control pool: Not applicable

- (3) Spillway crest: 5 ±
- (4) Test flood pool: 7 ±
- (5) Top dam: 7 ±

(g) Dam

- (1) Type: Concrete gravity and stone masonry
- (2) Length: 200 ft.
- (3) Height: 23 ft.
- (4) Top width: 2 ft. at spillway
- (5) Side slopes: Not applicable
- (6) Zoning: Not applicable
- (7) Impervious Core: Not applicable
- (8) Cutoff: Unknown
- (9) Grout curtain: Unknown

(h) Diversion and Regulating Tunnel

Not applicable

(i) Spillway

- (1) Type: Concrete gravity
- (2) Length of weir: 128 feet
- (3) Crest elevation: 321.0
- (4) Gates (see regulating outlets)
- (5) U/S Channel: Width of river
- (6) D/S Channel: Width of river
- (7) General:

(j) Regulating Outlets

The operable regulating outlets consist of a 4 foot wide, 6 foot high sluiceway outlet in the left side of the

spillway and an 8 foot wide gate which discharges through an elliptical conduit 9 feet, 4 inches wide and 7 feet, 5 inches high into a diversion canal that leads to Hillsborough Mill.

The invert elevations are 312.6 for the sluiceway and 313.2 for the elliptical conduit. The sluiceway is controlled by a 3 foot, 8 inch diameter hand wheel which operates a horizontal sliding steel waste gate. The hand wheel is located in the adjacent gatehouse. The 8 foot wide gate is controlled by an electrically driven multiple gearing system which activates two rack gears.

## SECTION 2 - ENGINEERING DATA

### 2.1 Design Records

The design of the dam is quite simple and incorporates no unusual features. Several design drawings dated in 1912 are available for the dam and are included in Appendix B. None of the original design calculations are available.

### 2.2 Construction Records

No construction records are available for this dam.

### 2.3 Operational Records

The only operational record of value is that the water level at the dam was about 8 feet above the spillway crest during the 1938 flood.

### 2.4 Evaluation

#### (a) Availability

The absence of detailed design drawings and calculations is a significant shortcoming. An overall unsatisfactory assessment for availability is therefore warranted.

#### (b) Adequacy

The lack of in-depth engineering data does not permit a definitive review. Therefore, the adequacy of the dam cannot be assessed from the standpoint of reviewing design and construction data. This assessment is based primarily on the visual inspection, past performance, and sound engineering judgment.

#### (c) Validity

Since the observations of the inspection team generally confirm the information contained in the files of the New Hampshire Water Resources Board, a satisfactory evaluation for validity is indicated.

## SECTION 3 - VISUAL OBSERVATIONS

### 3.1 Findings

#### (a) General

The Hillsborough Mills Dam is in POOR condition at the present time.

#### (b) Dam

##### (1) Right Abutment Structure (Photo 8)

The upstream training wall is in fair condition. Minor surface erosion is visible and is attributed to ice damage. The gunite facing on the downstream training wall is cracked at stone joints. Efflorescence was observed at these cracks. The cyclopean concrete cap on the downstream training wall is spalled and has traces of efflorescence. The spalling is attributed to moisture intrusion which has been subjected to alternating freeze and thaw cycles.

##### (2) Spillway (Photos 4 through 8)

The spillway was constructed in three sections of approximately equal length. The right third of the structure (Photo 8) appears to have settled. All vertical construction joints are eroded to depths of 2 inches and widths of 2 inches. This erosion is attributed to cavitation and ice damage. The pressure relief drain (Photo 7) is located within the toe of the spillway adjacent to the vertical joint which is closest to the left end of the spillway. The concrete at this location is eroded for a length of 4 feet, a width of 12 inches, and a depth of 2 feet. The downstream face of the spillway, including the toe cut-off, is eroded in several places. Two horizontal construction joints (Photo 6), which extend over the entire length of the spillway, have opened. In some places these joints have eroded to widths of 12 inches and depths of 6 inches. The underside of the toe cut-off wall for the right and middle thirds of the spillway (Photo 6), has eroded to within 6 inches of its top surface. This erosion is attributed to scour and ice damage. The toe of the spillway at these locations is undermined. The left spillway section does not appear to be undermined.

After spillway construction a concrete apron was placed over rubble stone at the same elevation as the toe of the spillway. This apron has been destroyed (Photo 2).

Two rows of flashboard stanchion sockets are located over the entire length of the spillway crest (Photo 2). These sockets are 26 inches deep. Solid flashboard stanchions, which are 1.5 inches in diameter and extend 3 feet above crest elevation, are in place over the entire length of the structure. Most of the stanchions are bent from ice damage. Flashboards are located over approximately 50 percent of the spillway crest. The flashboards are in poor condition.

The horizontal sluice gate adjacent to the left end of the spillway is operated by a hand wheel in the gate house. The operating mechanism for this gate is in good condition, and representatives of the owner indicated that this gate is operable. Seepage at the rate of 1 to 2 gpm was flowing through the seated end of the gate at the time of inspection (Photos 4 and 5).

The ungated sluice opening located on the right end of the spillway (Figure B-3) is sealed with lumber planking set on the upstream face of the spillway. Available drawings indicate that a manually operated timber sluice gate was once in place at this location. There is no evidence of this past construction. This opening is used to lower the impoundment pool if the horizontal sliding gate is jammed or clogged with debris. The planking is either removed manually or with a small charge of dynamite. The sluice invert is about 6 feet below crest level.

### (3) Left Spillway End Structure

The top surface of the cyclopean concrete cap has spalled over 20 percent of its surface area to a depth of up to 2 inches (Photo 2). This spalling is attributed to moisture intrusion which has been subjected to alternating freeze and thaw cycles. The gunited portions of the structure and downstream training wall are in good condition with no evidence of displaced stones, bulges, or other signs of distress. The dry stone masonry wall extension is in poor condition with displaced stones, settlement, and bulges. Seepage at the rate of 10 to 20 gpm



is flowing through the joints of the dry stone masonry wall (Photo 3). The source of the seepage appears to be the adjacent millrace flume.

(4) Left Upstream Training Wall (Overview Photo)

The upstream face of this wall is spalled over 20 percent of its vertical face. Most of the spalling is concentrated at the spillway crest elevation and is attributed to ice damage. There are numerous random cracks on this wall.

The downstream end of the wall is eroded at the normal water level. This erosion is 1.5 feet high, 12 inches wide, and up to 6 inches deep. This erosion is attributed to ice damage.

(5) Gate House (Overview Photo)

The gate house is in fair condition. There is surface erosion of the interior face of the concrete foundation. This erosion is attributed to ice damage. The steel trash racks are rusted.

The sluice gate mechanical drive consists of a multiple gearing system which actuates two rack gears. The electrically driven mechanical drive system is well maintained. The gate was operated using this system. The owner's representative indicated that manual operation of the gate was extremely difficult.

### 3.2 Evaluation

The Hillsborough Mills Dam is in POOR condition at the present time. The spillway is severely deteriorated and in need of repair. The remaining components of the dam are in fair condition with varying degrees of concrete deterioration.

## SECTION 4 - OPERATIONAL PROCEDURES

### 4.1 Procedures

At present there is no set procedure for operating the dam. The gate leading to the canal is operable as is the horizontal sliding sluice gate. In the past the sealed sluiceway at the right of the spillway has been opened by removing planking either manually or with a small charge of dynamite. The practice of dynamiting should be discontinued.

### 4.2 Maintenance of Dam

There is no scheduled maintenance program for the dam. The deteriorated condition of the concrete is evidence of the lack of maintenance. When the horizontally sliding sluice gate becomes jammed the right sluiceway is opened to lower the pool so the left sluice gate can be cleared.

### 4.3 Maintenance of Operating Facilities

The operating facilities have been maintained in operating condition although there is no set prescribed maintenance procedure.

### 4.4 Description of Warning System

There is no formal warning system in effect for this dam.

### 4.5 Evaluation

The dam's present POOR condition is largely a result of the lack of maintenance performed at the dam. The spillway is deteriorated, undermined, and portions appear to have settled. The protective concrete apron is destroyed. The operating mechanisms are maintained in operating condition. The present maintenance program is not adequate for continued long-term use of the dam.

## SECTION 5 - HYDRAULICS/HYDROLOGY

### 5.1 Evaluation of Features

#### (a) General

The Hillsborough Mills Dam is a concrete gravity structure on the Souhegan River in Wilton, N.H. It is a run-of-the-river dam. It was built in 1912 and provided power to a downstream mill.

The drainage area is 97 square miles of predominantly forested, hilly terrain with steep slopes and narrow channels. There are numerous ponds, reservoirs, and wetland areas to detain run-off and thereby reduce peak flows.

#### (b) Design Data

Data sources include prior inventory and inspection reports and a Flood Insurance Study (FIS) performed by Anderson-Nichols Company (ANCO). The New Hampshire Water Control Commission's "Data on Dams in New Hampshire" (September 26, 1939) the Public Service Commission of New Hampshire's "Dam Record" (August 31, 1936); and the New Hampshire Water Resources Board's "Inventory of Dams and Water Power Developments" (August 28, 1936) and "Survey of Existing New Hampshire Dams" provide much of the basic data for the dam. Inspection reports dated June 6, 1940; July 11, 1951; and July 24, 1975 are also available.

ANCO provided copies of field data, computations, and drawings developed for an FIS which included the Souhegan River at the dam. Included were cross-section data and 10, 50, 100 and 500-year peak discharges at the dam. A topographic map and water surface profiles of the Souhegan River as it passes through Wilton and a flood boundary map of the river downstream of the dam were also included.

#### (c) Experience Data

A Water Control Commission questionnaire was completed by the dam's owners concerning the peak flood level experienced during September 21 through 24, 1938. The reported peak level was 8.5 feet above the spillway crest.

(d) Visual Observations

At the left abutment a concrete training wall rises 9.6 feet above the spillway crest. To the left of the gatehouse, however, the ground surface is only 4 feet above the spillway crest level. From this point the ground surface rises to the left at a moderate slope until it reaches a height of 9 feet above the spillway crest at the top of a small railroad embankment. Beyond the railroad embankment the ground surface drops off rapidly to a depression.

Downstream of the dam the Souhegan River has a moderate slope and is confined by steep, high banks. The stream bed is strewn with cobbles and boulders and is approximately 40 feet from toe-to-toe of the confining banks. Approximately 1.3 miles downstream the banks begin to recede and the channel becomes less confined. The transition continues until a point about 2 miles downstream from the dam, there is an extensive flood plain on each side of the river.

The Souhegan River is crossed by three bridges within 1.4 miles downstream of Hillsborough Mills Dam. The first bridge is a railroad bridge with two 18 foot high by 30 foot wide openings. A highway bridge near the Hillsborough Mills has two 40 foot wide arches with a maximum height of about 22 feet. Further downstream there is another highway bridge with a single 80 foot span approximately 18 feet above the stream bed. Other structures in this area are sufficiently high to be out of danger of flooding. About 1.5 miles downstream from the dam there are 5 or 6 buildings located 11 or 12 feet above the stream bed.

(e) Test Flood Analysis

The hydrologic conditions of interest in this Phase I investigation are those required to assess the dam's overtopping potential and its ability to safely allow an appropriately large flood to pass. This requires determining the discharge and storage characteristics of the structure to evaluate the impact of an appropriately sized Test Flood. None of the original hydraulic and design records are available for use in this investigation.

Guidelines for establishing a recommended Test Flood based on the size and hazard classifications of a dam are specified in the "Recommended Guidelines" of the Corps of Engineers. The impoundment of 70 acre-feet and height of 23 feet place the dam in the SMALL size category.

The hazard potential for the dam is in the LOW category. As shown in Table 3 of the Corps' of Engineers "Recommended Guidelines," the appropriate Test Flood for a dam classified as SMALL in size with LOW hazard potential would be between the 50 and 100 year floods. Where a range of values for the Test Flood is indicated, the magnitude should be related to the hazard potential. Because the dam is located in a developed area, the hazard potential is considered on the high side of the LOW category. The Test Flood flow is therefore based on the 100-year flood.

The previous ANCO FIS results provide estimated values for the 10, 50, 100 and 500-year discharges at the dam. These were computed by the SCS using the convex routing method and considering the storage effects of flood control dams built in this watershed by SCS. The computed 100-year flow rate is 7550 cfs. The surcharge storage volume of this dam is too small to have a significant effect on the peak rate of discharge. For this reason a stage-storage relation has not been calculated for the Hillsborough Mills Dam.

A stage-discharge curve is developed by defining discharge as the sum of flow over the spillway and over the side slope to the left of the spillway. The calculations determining this curve are documented in Appendix D.

The peak discharge of 7550 cfs with no flashboards in place would result in a stage 6.8 feet above the spillway crest with a flow depth of about 2.8 feet around the gate house at the left abutment. If the 4 feet high flashboards are in place across the entire length of the spillway, and assuming that these do not fail under flood conditions, the Test Flood would reach a stage more than 9 feet above the spillway crest. This would overtop the railroad embankment at the left bank. The extent and depth of overtopping is unknown.

(f) Dam Failure Analysis

The peak outflow that would result from a dam failure is estimated using the procedure suggested in the Corps' of Engineers New England Division April 1978 "Rule of Thumb Guidelines for Estimating Downstream Dam Failure Hydrographs." Failure is assumed to occur at the time the railroad embankment to the left of the

dam is just overtopped. This level was chosen, rather than the low area beside the gate house which is five feet lower, because historical flood stages have been as high as 8.5 feet above the spillway crest or 4.5 feet above the low spot without evident damage to the dam. Also past inventory reports and design data indicate freeboard of 8 to 9.5 feet above spillway crest. Based on the rating curve, the discharge at the dam would be 12,100 cfs with no flashboards in place for this elevation, which is 9.0 feet above the spillway crest and 9.1 feet above the tailwater at this discharge. Assuming a 51 foot gap is opened in the dam, the peak failure outflow through the gap and over the remainder of the dam would be 14,400 cfs.

This dam failure outflow should not be a hazard to the railroad bridge located one-half mile downstream or to either of the two highway bridges within a mile further downstream. All three have openings higher than the estimated flow depth of 16.8 feet, and none constrict the channel significantly.

Following the "Rule of Thumb Guidelines" for storage routing, it is estimated that, at the end of the first 1.5 mile reach downstream of the dam, the flood peak would be attenuated to 13,500 cfs. With an estimated depth of just over 11 feet, this flow should not cause serious flood damage to the buildings in this vicinity, although some minor flooding is a possibility. More significantly, the component of flow caused by a dam failure is only 1400 cfs, which represents incremental flood depths of about 0.5 feet above the level prior to dam failure. Beyond these buildings, the diminished dam failure flood wave will be essentially attenuated in the extensive flood plain.

## SECTION 6 - STRUCTURAL STABILITY

### 6.1 Evaluation of Structural Stability

#### (a) Visual Observations

##### (1) General

The field investigations revealed the possibility that the right end of the spillway may have settled. The cause of the destruction of the downstream concrete apron warrants further investigation. After these investigations, structural stability calculations should be prepared.

##### (2) Right Abutment Structure

This structure is in fair condition with some erosion and spalling of concrete. The gunite facing on the downstream training wall is cracked at stone joints.

##### (3) Spillway

The right third of the spillway has apparently experienced some settlement. All the vertical construction joints in the spillway are eroded. Some erosion has taken place in the downstream face and toe of the spillway. Two horizontal construction joints have opened. Undermining of the spillway toe has occurred under the right two-thirds of the structure. The concrete apron downstream of the toe has been destroyed.

##### (4) Left Spillway End Structure

The cyclopean concrete cap is spalled over 20 percent of its surface area. The gunited portions of the end wall and downstream training walls are in good condition. The dry stone masonry wall extension is in poor condition.

##### (5) Left Upstream Training Wall

The upstream face of the wall is spalled over 20 percent of its vertical face. The downstream end of the wall is eroded at the normal water level.

(6) Gate House

The gate house is in fair condition. There is surface erosion of the interior face of the concrete foundation.

(b) Design and Construction Data

The plans for this dam would be of some assistance in performing a stability calculation. Most of the dimensions would have to be checked in the field. No calculations of value to a stability analysis are available.

(c) Operating Records

A questionnaire filled out by the owners in 1938 indicated that the 1938 flood caused a stage at the dam of 8.5 feet above the spillway crest. It is not clear that the dam is in the same condition now as it was at that time. It is also not clear whether the flashboards were in place then.

(d) Post Construction Changes

The primary post construction change was the addition of the concrete apron downstream from the spillway. It is not known when this apron was built or when it was destroyed.

(e) Seismic Stability

The dam is located in Seismic Zone No. 2 and, in accordance with recommended Phase 1 guidelines, does not warrant seismic analysis.



SECTION 7 - ASSESSMENT, RECOMMENDATIONS,  
AND REMEDIAL MEASURES

7.1 Dam Assessment

(a) Condition

The Hillsborough Mills Dam is in POOR condition at the present time.

(b) Adequacy of Information

The lack of in-depth engineering data does not permit a definitive review. Therefore, the adequacy of this dam cannot be assessed from the standpoint of reviewing design and construction data. This assessment is based primarily on the visual inspection, past performance, and sound engineering judgment.

(c) Urgency

The recommendations and improvements contained herein should be implemented by the owner within one year of receipt of this report.

(d) Need for Additional Investigation

Additional investigations should be performed by the owner as outlined in Paragraph 7.2 below.

7.2 Recommendations

It is recommended that the services of a registered professional engineer be retained to perform the following:

- a) Investigate the possible settlement of the spillway. Borings to determine soil conditions and possible seepage conditions should be part of this study.
- b) Investigate the undermining of the spillway toe.
- c) Investigate the cause of the destruction of the concrete apron.
- d) Prepare stability calculations for the dam.
- e) Investigate settlement and seepage through the left downstream training wall.
- f) Raise the low portion of the dam at the left side.

### 7.3 Remedial Measures

It is recommended that the following remedial measures be performed:

- a) Repair all vertical and horizontal construction joints in the spillway.
- b) Repair all spalled and eroded concrete on the various structures of the dam. These include the spillway, right and left abutment structures, the gate house, and the left upstream training wall.
- c) Institute a program of annual technical inspections.
- d) Discontinue the procedure of dynamiting open the sluice opening near the right end of the spillway.
- e) Immediately remove existing flashboards until remedial measures have been completed.

### 7.4 Alternatives

If it is decided to maintain the dam in continued use, there are no meaningful alternatives to these recommendations and remedial measures.

APPENDIX A  
VISUAL INSPECTION CHECKLIST

## INSPECTION TEAM ORGANIZATION

Date: November 8, 1978

NH 00258  
HILLSBOROUGH MILLS DAM  
Wilton, New Hampshire  
Souhegan River  
NHWRB No. 254.01

Weather: Overcast, 55°F ±

### INSPECTION TEAM

Nicholas Campagna	Goldberg, Zoino, Dunnicliff & Associates, Inc. (GZD)	Team Captain
Robert Minutoli	GZD	Geotechnical
Andrew Christo	Andrew Christo Engineers (ACE)	Structural
Paul Razza	ACE	Concrete
Guillermo Vicens	Resource Analysis, Inc.	Hydrology

The inspection team was accompanied by Mr. Pattu Kesavan of the New Hampshire Water Resources Board, and Messrs. Norm Draper and Ray Smith of the Abbott Machine Tool Company. Mr. Smith operated the sluice gate for the canal.

CHECK LISTS FOR VISUAL INSPECTION

AREA EVALUATED	BY	CONDITION & REMARKS
DAM SUPERSTRUCTURE		
A. General		
Vertical alignment and movement	AC	Right third of spillway has settled 1 to 2 inches
Horizontal alignment and movement		No deficiencies noted except in downstream left training wall (see below)
B. Right Abutment Structure		
Condition of concrete		Fair
Spalling		Concrete cap exhibits minor spalling
Erosion		Minor on upstream training wall
Cracking		Guniting facing cracked at location of joints in stone masonry
Rusting or staining of concrete		None noted
Visible reinforcing		None noted
Efflorescence		In cracks of guniting facing. Downstream training wall effloresced
Seepage		None noted
C. Left Abutment Structure		
Cyclopean concrete cap		Spalled over 20% of its top surface
Stone masonry walls, guniting faced	AC	No deficiencies noted

CHECK LISTS FOR VISUAL INSPECTION

AREA EVALUATED	BY	CONDITION & REMARKS
Dry stone masonry wall	AC	Displaced stones, settlement and bulging. Seepage at the rate of 10 to 20 gpm
D. Left Upstream Training Wall		
Condition of concrete		Fair
Spalling		Over 20% of upstream vertical face
Erosion		Downstream end, 1.5' x 1.0' x 0.5' deep
Cracking		Random cracks
Rusting or staining of concrete		None noted
Visible reinforcing		None noted
Efflorescence		None noted
Seepage	AC	None noted
OUTLET WORKS		
A. Spillway		
Condition of concrete	PR	Poor
Spalling		See erosion
Erosion	PR	All vertical construction joints eroded 2" wide x 2" deep. Erosion at pressure relief drain 4' long x 1.0' wide and up to 2' deep. Horizontal joints eroded up to 12" wide and 6" deep. Underside of toe eroded to within 6" of top surface. Minor erosion of entire downstream face of spillway

CHECK LISTS FOR VISUAL INSPECTION

AREA EVALUATED	BY	CONDITION & REMARKS
Cracking	PR	Open construction joints
Rusting or staining of concrete		None noted
Visible reinforcing		None noted
Efflorescence		None noted
Seepage		At the rate of 5 to 10 gpm through pressure relief drain
Left sluice gate		Good operating condition; seepage at the rate of 1 to 2 gpm due to unseated condition. Steel gate exhibits minor rusting
Right sluiceway		Operable when lumber planks removed
Flashboards		Poor condition
Flashboard stanchions		Poor condition
E. Gate House		
Condition of building	PR	Fair
Concrete foundation		Surface erosion on inside face of wall
Steel trash racks		Surface rust
Sluice gate	NAC	Good operating condition
RESERVOIR		
A. Shoreline		
Evidence of slide		None noted
Potential for slides		Shoreline stable
B. Sedimentation		Siltation at the left side of spillway extends about one foot above spillway crest behind flashboards

HILLSBOROUGH MILL DAM  
Wilton, N.H.

November 8, 1978  
NH 00258

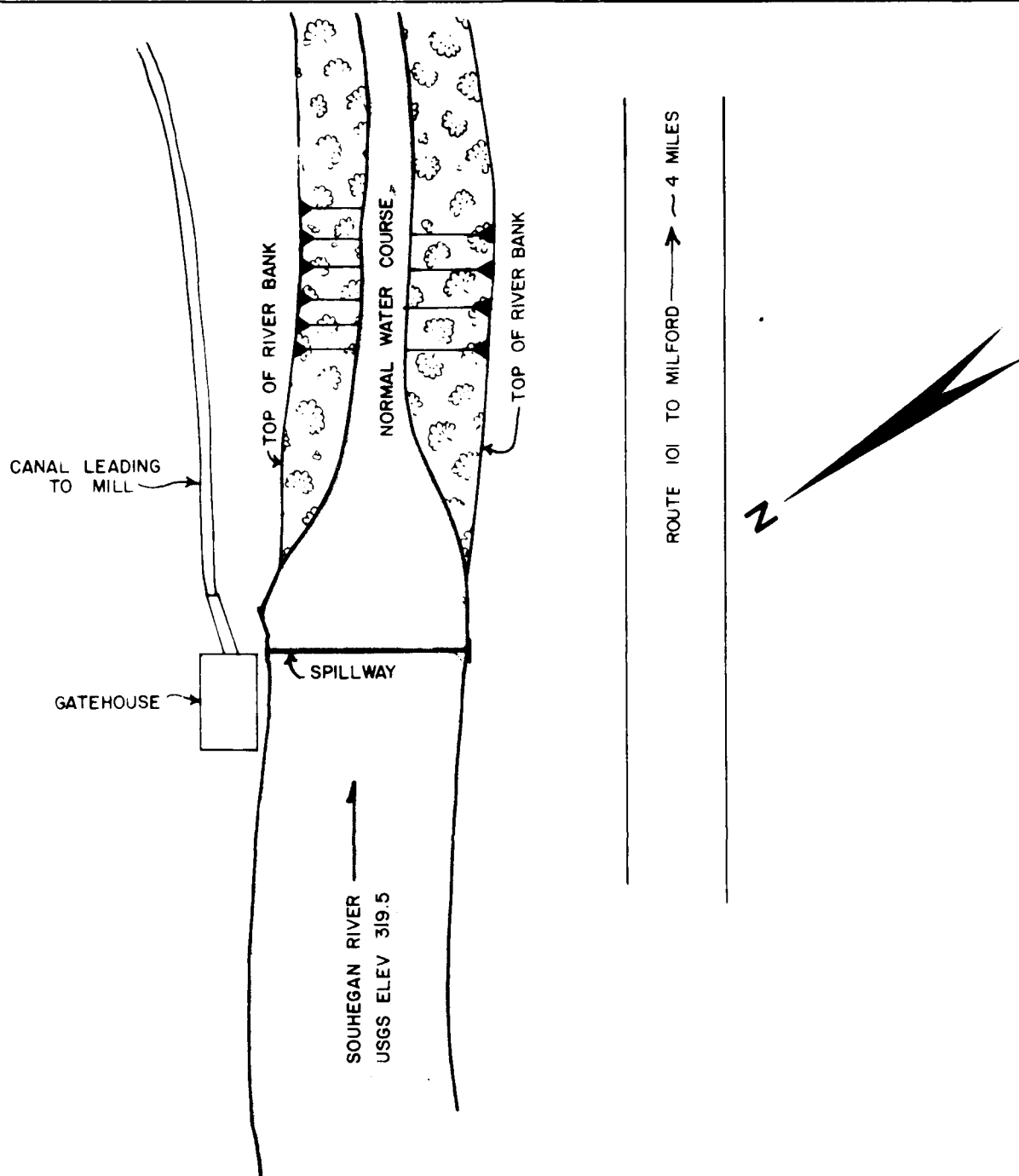
CHECK LISTS FOR VISUAL INSPECTION

AREA EVALUATED	BY	CONDITION & REMARKS
C. Upstream Hazard Areas in the Event of Back- flooding	NAC	None noted
D. Changes in Nature of Watershed	NAC	None noted



## APPENDIX B

	<u>Page</u>
FIGURE 1      Site Plan	B-2
Plan and Section of Dam	B-3
Plan and Section of Flume	B-4
Drawings of Water Power Development	B-5
Plan, Elevation and Section of Dam	B-6
List of Pertinent Data Not Included and Their Location	B-7



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GEOTECHNICAL CONSULTANTS  
NEWTON UPPER FALLS, MASS.

U.S. ARMY ENGINEER DIV. NEW ENGLAND  
CORPS OF ENGINEERS  
WALTHAM, MASS.

NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

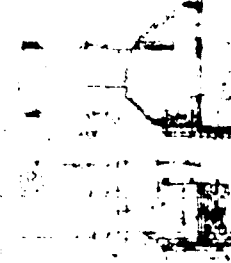
## SITE PLAN

HILLSBOROUGH MILLS DAM

NEW HAMPSHIRE

SCALE 1" = 100'

DATE NOVEMBER 1978

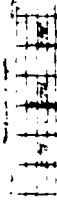


1. 100 ft. from shore

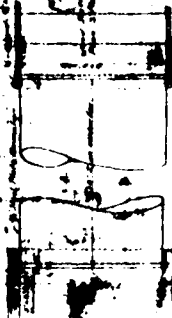
1. 100 ft. from shore  
2. 100 ft. from shore  
3. 100 ft. from shore

NOTE: DRAWING HAS BEEN REDUCED  
SCALES ARE NOT AS SHOWN

1. 100 ft. from shore



1. 100 ft. from shore



1. 100 ft. from shore



1. 100 ft. from shore

NOYE DRAWING HAS BEEN REDUCED  
SCALES ARE NOT AS SHOWN

SECRET  
NOV 1960  
MILITARY  
NOV 1960

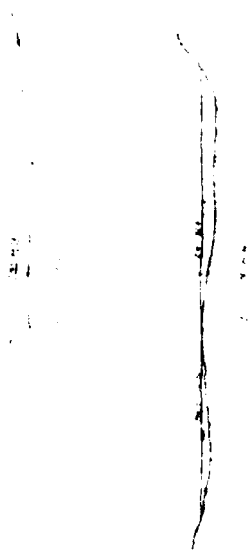
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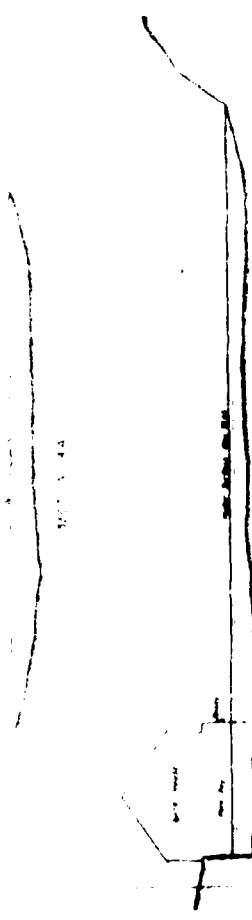
2

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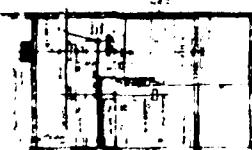
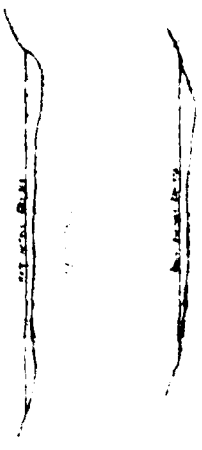
1994-1995



SECTION AA



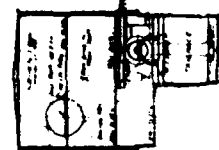
SECTION BB



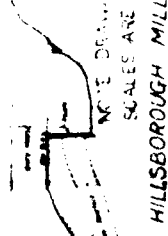
SECTION DD



SECTION EE



SECTION FF



SECTION GG

NOTE: DRAWINGS OF THE SECTIONS  
SCALES ARE NOT AS SHOWN

HILLSBOROUGH MILLS  
DRAWINGS OF WATER POWER DEVELOPMENT  
ON THE SO. MEGAN RIVER NEAR HILLSBOROUGH  
MASS.

SCALE OF FEET  
1" = 10'

SCALE OF FEET  
1" = 10'

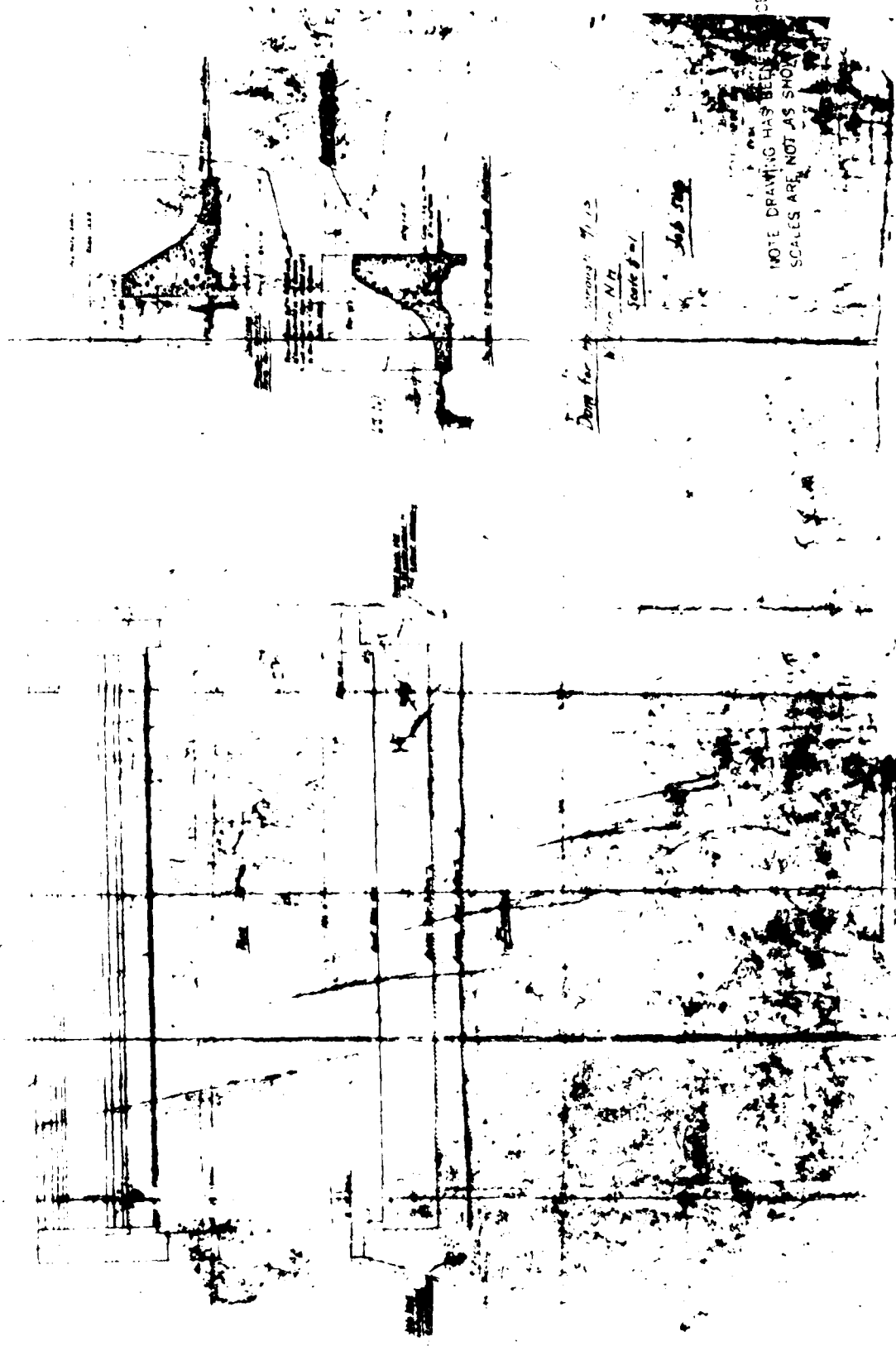
SCALE OF FEET  
1" = 10'

SCALE OF FEET  
1" = 10'

SCALE OF FEET  
1" = 10'

REPRODUCED AT GOVERNMENT EXPENSE

18



Propeller

Scale 1/2"

Job 500

NOTE: DRAWING HAS BEEN REPRODUCED  
SCALES ARE NOT AS SHOWN

E. B.

The New Hampshire Water Resources Board (NHWRB) located at 37 Pleasant Street, Concord, N.H. 03301, maintains a correspondence file for this dam. Some of the data included in this file are listed below:

- 1) Inspection reports from June 6, 1940; July 11, 1951; and July 24, 1975.
- 2) The New Hampshire Water Control Commission's "Data on Dams in New Hampshire" (September 26, 1939) and "Data on Water Power Developments in New Hampshire" (September 26, 1939).
- 3) The New Hampshire Public Service Commission's "Dam Record" (August 31, 1936).
- 4) NHWRB's "Inventory of Dams and Water Power Developments" (August 28, 1936) and "Survey of Existing New Hampshire Dams."

Anderson Nichols Company performed a Flood Insurance Study of the Souhegan River including cross-section data and calculation of various design flood flows.

APPENDIX C  
SELECTED PHOTOGRAPHS



CANAL LEADING  
TO MILL

GATEHOUSE

TOP OF RIVER BANK

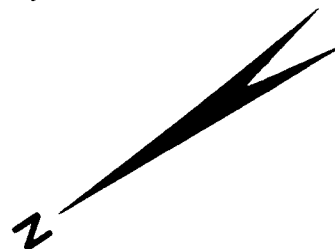
NORMAL WATER COURSE

TOP OF RIVER BANK

SPILLWAY

SOUHEGAN RIVER  
USGS ELEV 319.5

ROUTE 101 TO MILFORD ~ 4 MILES



➔ OVERVIEW

➤ APPENDIX C

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## LOCATION AND ORIENTATION OF PHOTOS

FILE NO. 2201

HILLSBOROUGH MILLS DAM

NEW HAMPSHIRE

SCALE 1" = 100'

DATE NOVEMBER 1978



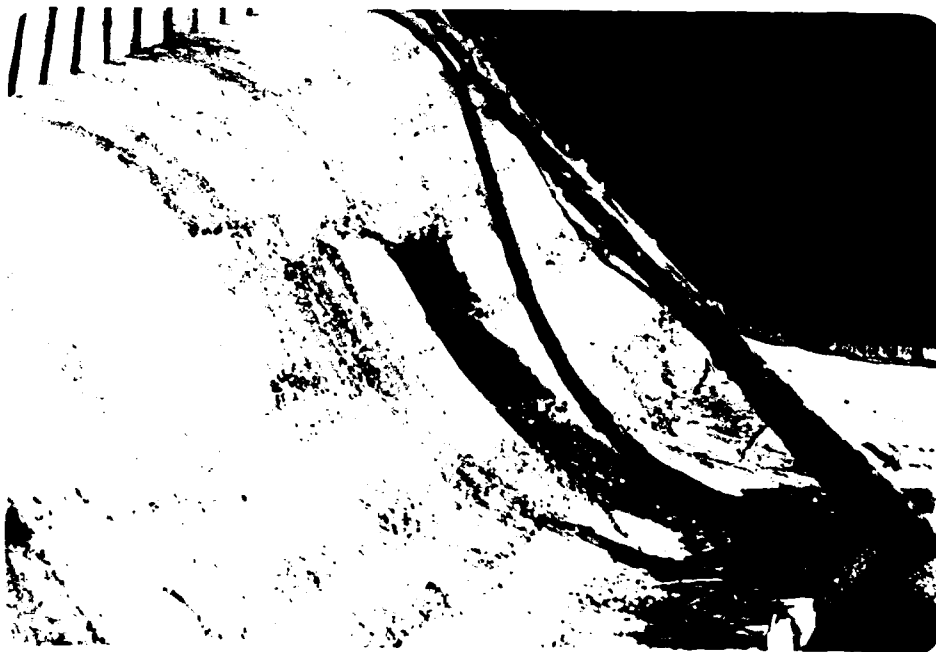
1. View of downstream channel from right abutment



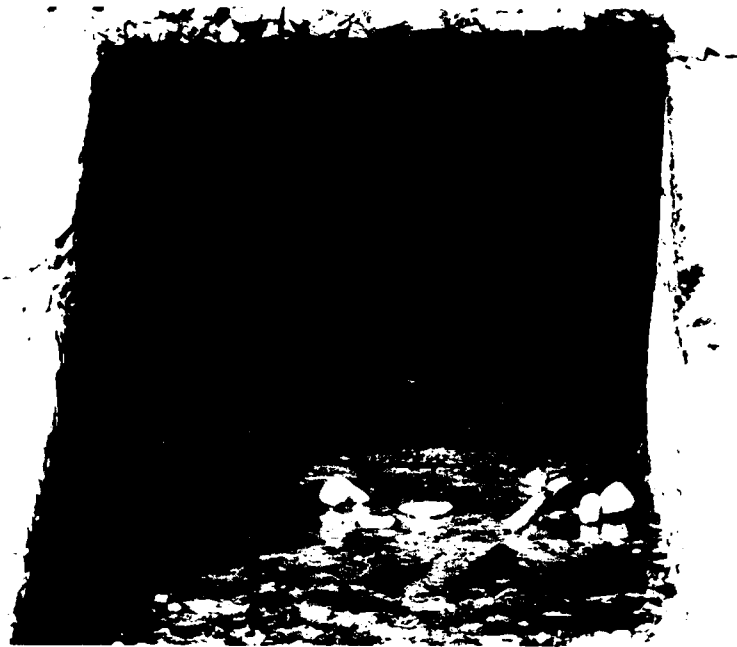
2. View from right abutment of left abutment showing guniting of squared stone masonry training wall and displaced apron



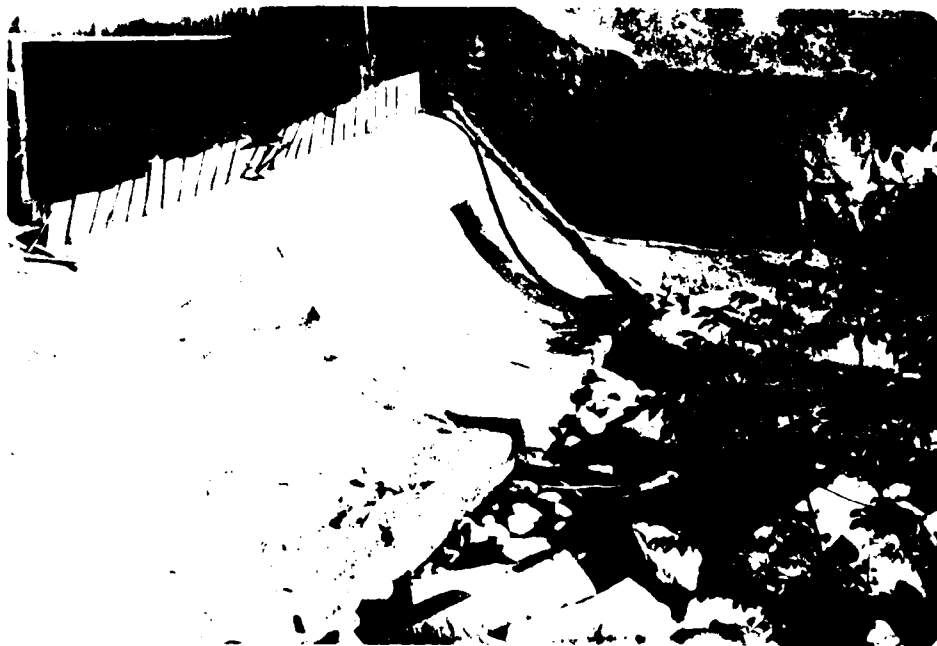
3. Detail of left downstream training wall showing seepage through rubble



4. View from downstream channel of left side of spillway showing leakage through old sluiceway



5. Detail of sluiceway from downstream



6. View of spillway from right abutment showing horizontal and vertical cracks and general deterioration



7. Detail of jointing and cracks in spillway and of pressure relief drain at toe



8. Right abutment structure and  
spillway

APPENDIX D  
HYDROLOGIC/HYDRAULIC COMPUTATIONS

## I Dam Rating Curve

See page 2 for a schematic sketch of the Hillsborough Dam overflow section, based mainly on FIS survey data and recent inspection at the site. Flashboards, roughly 4' high, are in place (tenuously) across the top of approx. half the spillway crest. These are ignored in the sketch and in the following calculations. This will affect the accuracy of the dam rating at low stages. However, the flash boards will be destroyed in a flood and so will not affect the dam rating at high stages.

## Spillway Overflow

$$Q_1 = CL H^{3/2}$$

$$C = 3.3$$

$$L = 128'$$

$$H = \text{head on crest} \quad (\text{datum} = \text{elev. } 321.0)$$

$$Q_1 = 3.3 \times 128 \times H^{3/2}$$

## Left Bank Overflow

$$Q_2 = CL H_2^{3/2}$$

$$C = 2.8$$

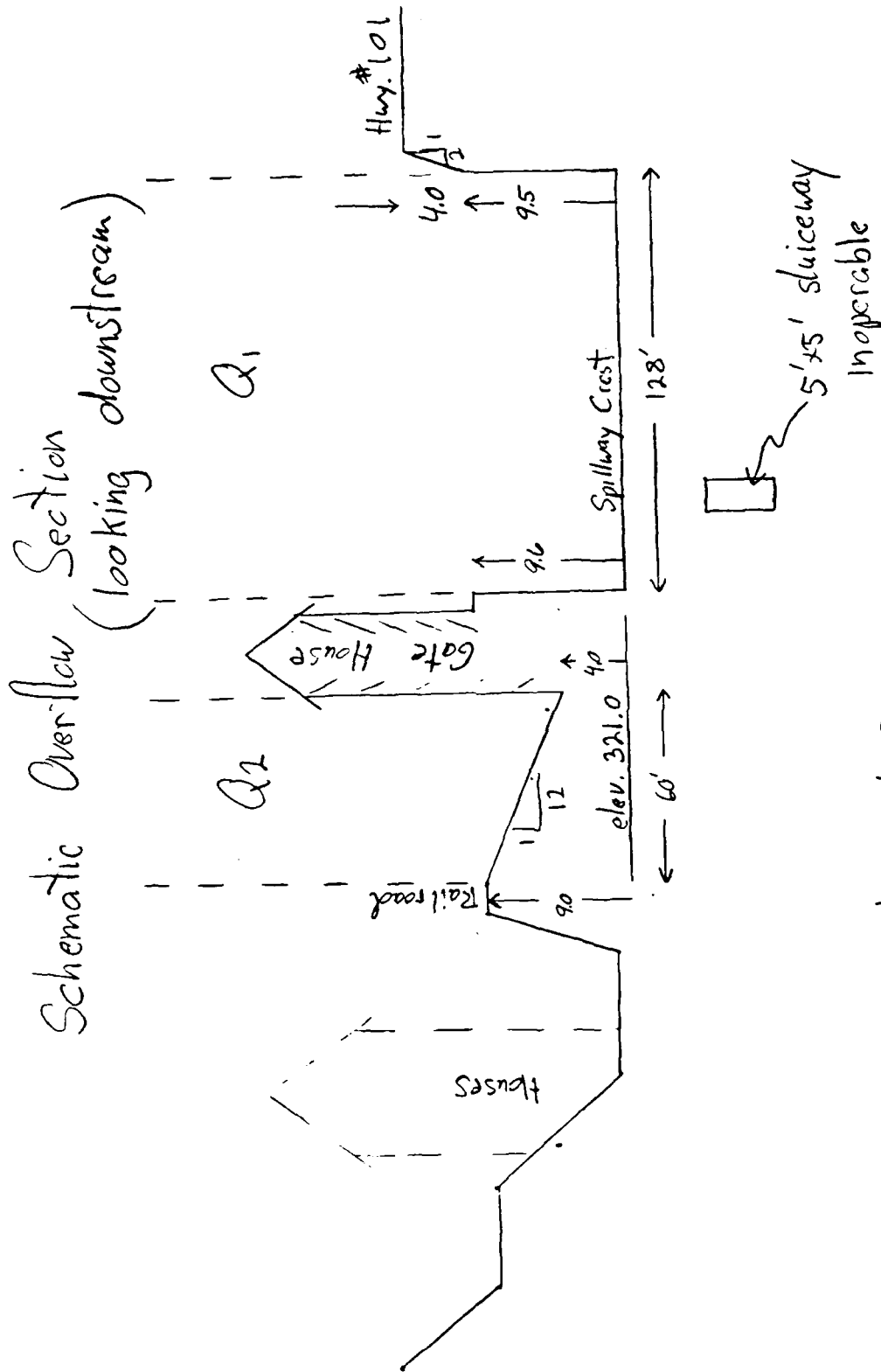
$$L = 12(H-4)$$

$$H_2 = 0.5(H-4) \quad (\text{avg. head})$$

$$Q_2 = 2.8 \times 12(H-4) \times (0.5(H-4))^{3/2}$$

D-2





Hillsborough Mills Dam

Sluiceway

Inoperable

$$Q_3 = 0$$

Canal Headgate

Assume that the outlet to the flume and canal is closed at time of flooding. This is normally the case.

$$Q_4 = 0$$

The resulting values calculated in this way agree quite closely with values taken from FIS profiles.

4/20

```
LIST
100 REMARK: STORED ON TAPE 18, FILE 54
110 REMARK: STAGE-DISCHARGE FUNCTION FOR HILLSBOROUGH DAM
120 PAGE "DISCHARGE FROM HILLSBOROUGH DAM"
130 PRINT USING 150:
140 PRINT /2T"HEAD"30T"DISCHARGE"
150 IMAGE USING 170:
160 PRINT 1T"(FEET)"32T"(CFS)"
170 IMAGE USING 190:
180 PRINT 10T"TOTAL
190 IMAGE 10T"TOTAL
200 FOR H=0 TO 9 STEP 0.5
210 Q1=3.3*128*H↑1.5
220 Q2=0
230 IF H<=4 THEN 250
240 Q2=2.8*12*(H-4)*(0.5*(H-4))↑1.5
250 Q3=Q1+Q2
260 PRINT USING 270:H,Q3,Q1,Q2
270 IMAGE 2T,20.20,90,8X,100,110
280 NEXT H
290 END
```

SPILLWAY LEFT BANK"

5/20

# DISCHARGE FROM HILLSBOROUGH DAM

HEAD (FEET)	TOTAL	DISCHARGE (CFS) SPILLWAY	LEFT BANK
0.00	0	0	0
0.50	149	149	0
1.00	422	422	0
1.50	776	776	0
2.00	1195	1195	0
2.50	1670	1670	0
3.00	2195	2195	0
3.50	2766	2766	0
4.00	3379	3379	0
4.50	4034	4032	2
5.00	4734	4723	123
5.50	5481	5448	37
6.00	6275	6208	67
6.50	7117	7000	117
7.00	8008	7823	185
7.50	8948	8676	272
8.00	9938	9558	390
8.50	10978	10468	510
9.00	12069	11405	664

Dam Safety

Hillsborough

DHF

6-5-79 (follows 5/20)<sup>u</sup>

Assuming that 4' flashboards are in place across the entire length of the spillway, and assuming that they do not "trip" or fail under flood conditions, the dam rating curve would be revised as follows

Spillway Overflow

$$Q_1 = CL H_1^{3/2}$$

$$C = 3.3$$

$$L = 128'$$

$$H_1 = H - 4 \quad (\text{head on flashboard crest with } H \text{ measured from the permanent crest -- elev. 321.0})$$

$$Q_1 = 3.3 \times 128 \times (H - 4)^{3/2}$$

$Q_2, Q_3$ , and  $Q_4$  will be unchanged

A rating table for this case is shown on the next page.

For higher stages ( $H > 9'$ ), the railroad embankment which runs along the left bank of the river would be overlapped for a considerable distance upstream, and a flow channel parallel to the river would develop on the far side of this embankment.

# DISCHARGE FROM HILLSBOROUGH DAM W/ FLASHBOARDS

HEAD (FEET)	TOTAL	DISCHARGE (CFS) SPILLWAY	LEFT BANK
0.00	0	0	0
0.50	0	0	0
1.00	0	0	0
1.50	0	0	0
2.00	0	0	0
2.50	0	0	0
3.00	0	0	0
3.50	0	0	0
4.00	0	0	0
4.50	151	149	2
5.00	434	422	12
5.50	809	776	33
6.00	1262	1195	67
6.50	1787	1670	117
7.00	2380	2195	185
7.50	3039	2766	272
8.00	3759	3379	380
8.50	4543	4032	510
9.00	5387	4723	664

DATUM IS PERMANENT SPILLWAY CREST--ELEV. 321.0

(follows <sup>b</sup> 5/21)

Dam Safety

Hillsborough

RHF  
6-5-79

(Follows 5/2)

bankment. Even if sufficient data were readily available, this flow condition would be too complex to be attempted in a study of this type.

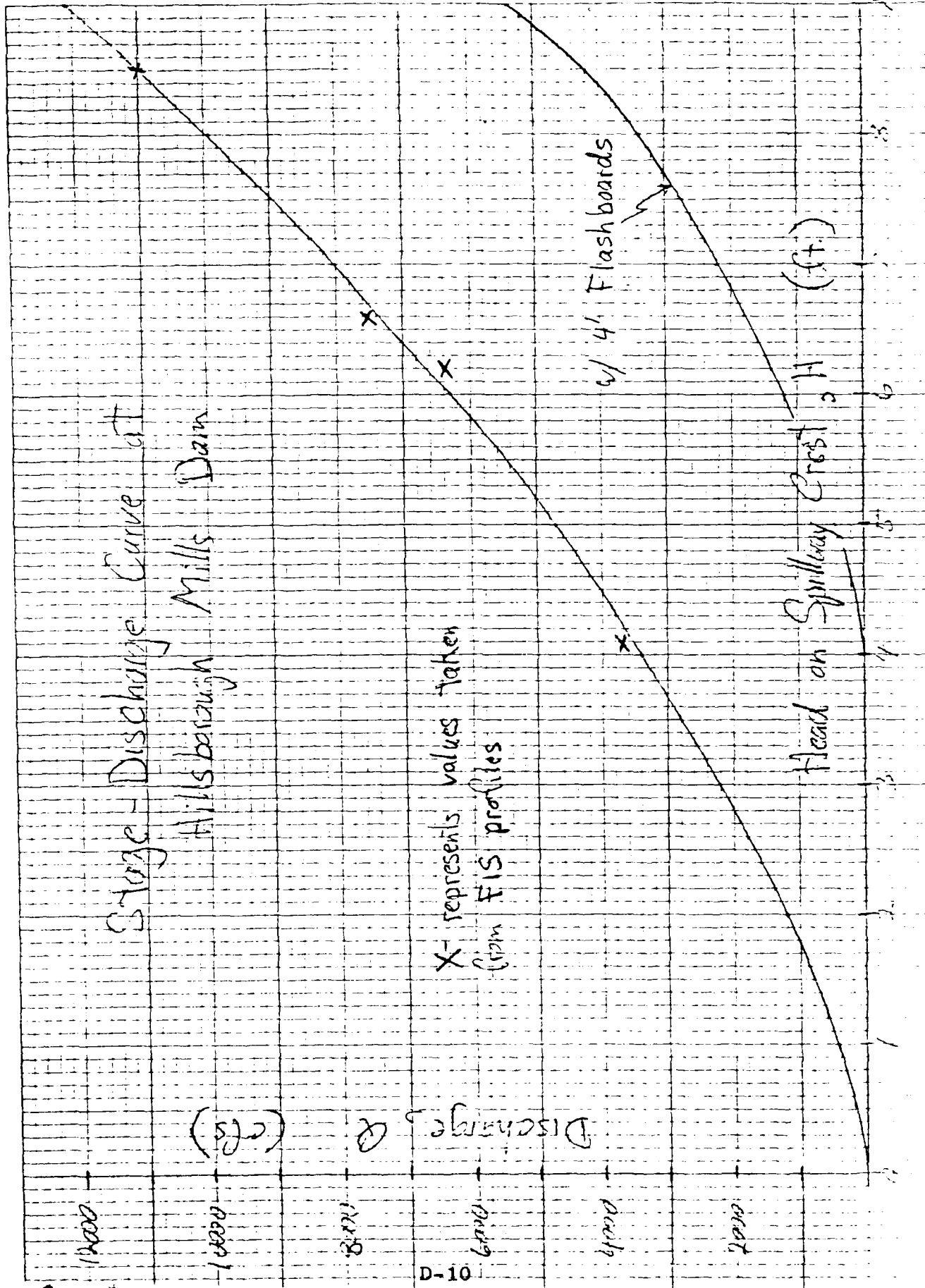
# Stage - Discharge Curve at Hillsborough Mills Dam

Discharge,  $Q$  (cfs)

X - represents values taken  
from FIS profiles

w/ 4' Flashboards

Head on Spillway Crest,  $H$  (ft.)





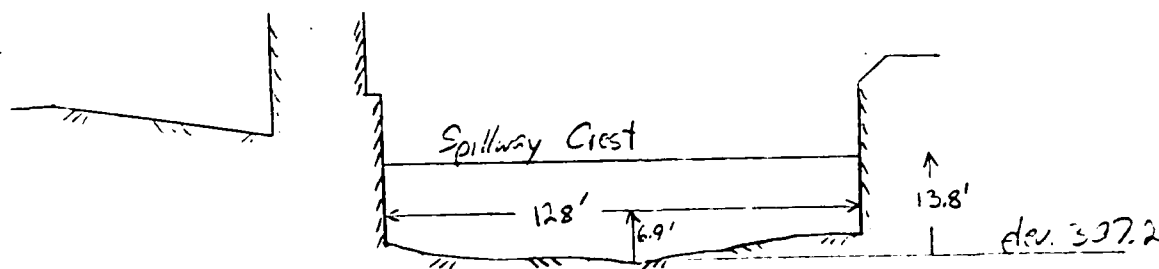
## II Dam Failure Analysis

Outflow at Failure = Calculated outflow through breach + Normal outflow under assumed preconditions to failure

Assume that failure occurs when the railroad track to the left of the dam is overtopped at elev. 330 \*  $H = 9'$

Normal Outflow

$$Q_{\text{normal}} = 12070 \text{ cfs}$$



Simplified Sectional View of Dam

\* This level has been chosen because historic flood stages as great as 8.5' above the spillway crest have been reported without evident damage to the dam. Also, the NHLMR and AE report<sup>D-11</sup> freeboard for this dam 8'

1.5 Dam Safety Hillsborough RHF  
and 9.5' above the spillway crest. 3/12/77 2/1920

### Breach Outflow

$$Q_{p1} = 8/27 \times W_b \times \sqrt{g} \times Y_0^{3/2}$$

$W_b$  = breach width

$$\leq 0.4 \times (\text{width of dam at } 1/2 \text{ height})$$

$$\text{use } W_b = 0.4 \times 128 = 51'$$

$Y_0$  = depth from top of pool to tail-water at failure

use tailwater elev. 320.9

based on FIS results

$$T_R = 500 \text{ yr.}$$

$$Q = 11,000 \text{ cfs}$$

$$Y_0 = 330.0 - 320.9 = 9.1'$$

$$Q_{p1} = 8/27 \times 51 \times \sqrt{g} \times 9.1^{3/2} = 2350 \text{ cfs}$$

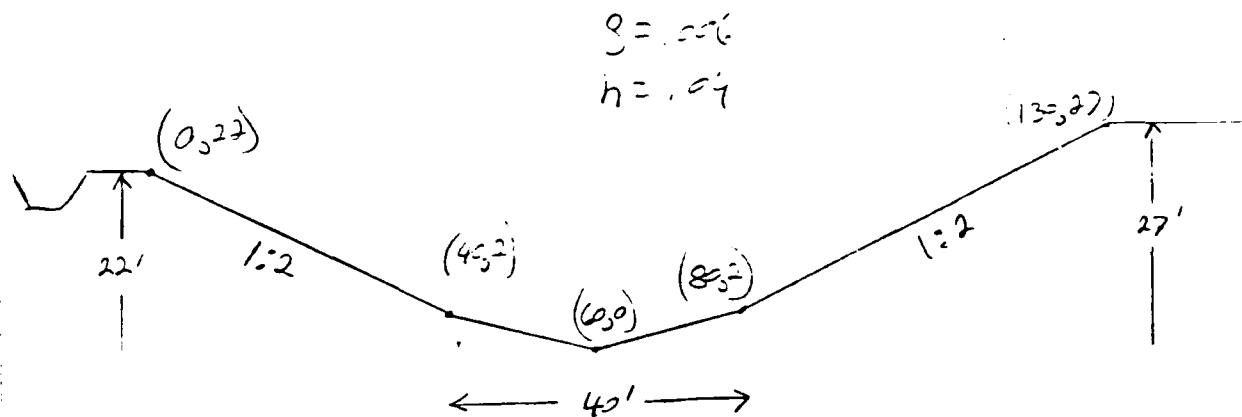
Total Outflow in River Channel

$$Q = 12070 + 2350 = 14420 \text{ cfs}$$

Downstream Flooding  
See map on following page.

FIS water surface profiles or computations  
were not at hand to supplement the computations which follow

Reach 1



Approx. Section of Souhegan R.  
d/s of Hillsboro Dam

A simple BASIC program was used to calculate a rating table based on the section sketched above. The table is shown on page 11.

[illegible]

D-14

11/20

DEPTH	ELEV	AREA	MPER	HYD-R	AR2/3	Q
0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.0	1.0	10.0	20.1	0.5	0.3	18.1
2.0	2.0	40.0	40.2	1.0	6.3	115.0
3.0	3.0	82.0	44.7	1.8	39.9	354.8
4.0	4.0	128.0	49.1	2.6	123.0	699.4
5.0	5.0	178.0	53.6	3.3	242.4	1143.4
6.0	6.0	232.0	58.1	4.0	396.3	1685.9
7.0	7.0	290.0	62.6	4.6	584.3	2327.5
8.0	8.0	352.0	67.0	5.3	806.7	3070.1
9.0	9.0	418.0	71.5	6.0	1064.0	3916.2
10.0	10.0	488.0	76.0	6.8	1357.3	4868.4
11.0	11.0	562.0	80.4	7.5	1687.3	5929.7
12.0	12.0	640.0	84.9	8.1	2055.1	7103.2
13.0	13.0	722.0	89.4	8.6	2461.8	8392.0
14.0	14.0	808.0	93.9	9.1	2908.2	9799.3
15.0	15.0	898.0	98.3	9.6	3396.2	11328.6
16.0	16.0	992.0	102.3	10.2	3926.4	12982.5
17.0	17.0	1090.0	107.3	10.7	4499.4	14764.9
18.0	18.0	1192.0	111.8	11.2	5117.2	16678.8
19.0	19.0	1298.0	116.2	11.7	5780.4	18727.2
20.0	20.0	1408.0	120.7	12.2	6490.4	20913.6
21.0	21.0	1522.0	125.2	12.7	7248.1	23241.0
22.0	22.0	1640.0	129.6	13.4	8054.8	25712.5
23.0	23.0	1761.0	131.9	14.0	8911.3	28623.8
24.0	24.0	1884.0	134.1	14.7	9920.3	31676.4
25.0	25.0	2009.0	136.4	15.4	10978.3	34870.1
26.0	26.0	2136.0	138.6	16.1	12085.1	38204.9
27.0	27.0	2265.0	140.8		13240.9	41680.8
					14445.6	

STREAM RATING

SOUHEGAN RIVER  
D/S OF HILLSBOROUGH DAM

165 Lam Safety Hillsborough

KHR  
3/12/79

12/20

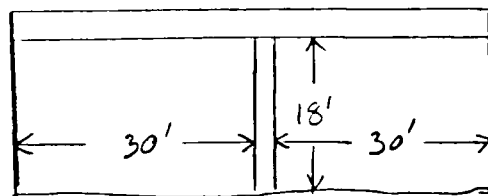
$$Q_{\text{normal}} = 12070 \text{ cfs}$$

$$\text{Flood depth} \approx 15.5'$$

$$Q_{\text{dam break}} = 14420 \text{ cfs}$$

$$\text{Flood depth} \approx 16.8'$$

Railroad Bridge  $\frac{1}{2}$  mile d/s of dam

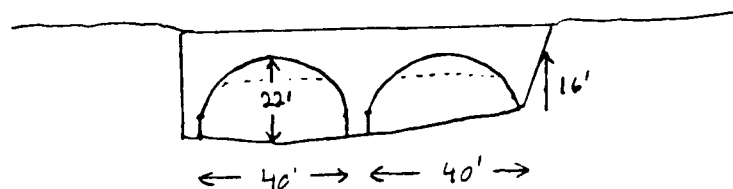


$$\begin{aligned} \text{Flow area at depth of } 16.8' \\ = 60 \times 16.8 = 1008' ^2 \end{aligned}$$

$$\begin{aligned} \text{Flow area of natural channel at depth of } 16.8' \\ \approx 1070' ^2 \end{aligned}$$

Bridge represents little constriction. Flow depth should not reach lower chord.

Highway Bridge 3000' d/s of dam



Flow area at depth of 16.8'  
 $\approx 33 \times 16.8 + 33 \times 14 = 1016' ^2$

Bridge represents little constriction. Flow depths should not reach top of opening

Estimate attenuated peak 1.5 miles d/s i.

Volume of impounded water

The quantity of water released by the dam failure is that volume above the normal flow level. Since the tailwater is nearly at the spillway crest under the assumed failure conditions, estimate this volume equal to the normal surface area times the head on the crest.

Surface Area = 5 acres (COE, normal pond)  
 $H = 9'$

use  $S = 9 \times 5 = 45$  AF

Volume of storage in the channel

Length  $\approx 1.5$  miles  $\approx 8000'$

Surface width  $\approx 40 + 2 \times 2 \times 14$   
 $= 96'$   
 Aug. depth above normal flow  $\approx 1'$

(Based on section sketched on p. w/ depth = 16'. This is representative of most of the reach)

guess

$Vol = 8000 \times 96 \times 1.0 \div 43560 = 17.6$  AF

Dam break flow peak component

$Q_{p2} = Q_{p1} \left(1 - \frac{Vol}{S}\right)$   
 $= 2350 \left(1 - \frac{17.6}{45}\right) = 1430$  cfs

Total attenuated peak flow

$Q = 12070 + 1430 = \underline{13500}$  cfs

check: flow depth  $= 16.3'$  (from stream rating, p.)

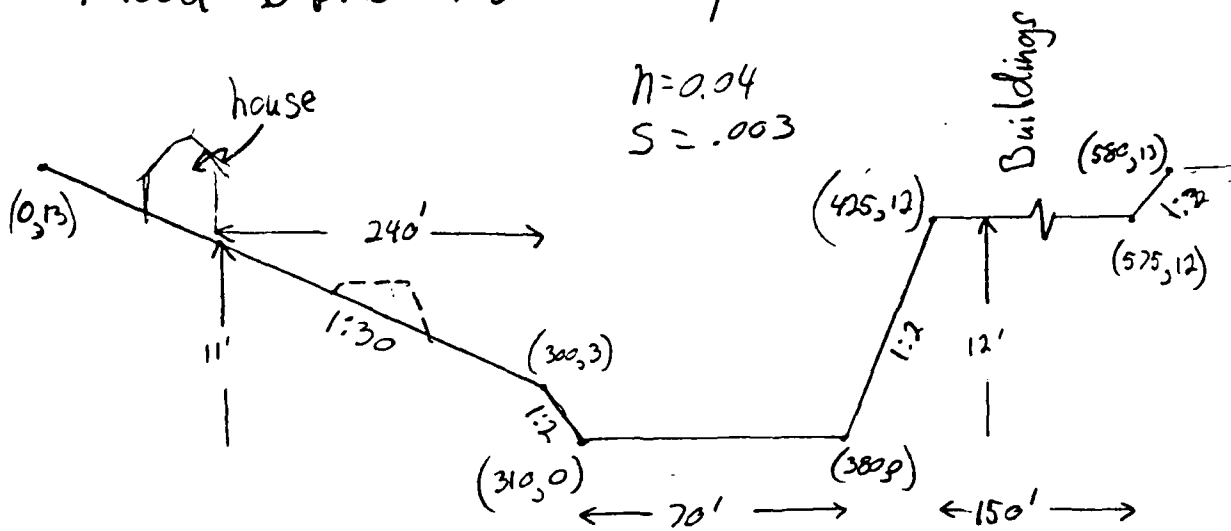
avg depth  $= \frac{16.8 + 16.3}{2} = 16.55$

avg depth above normal flow

$= \overset{D-18}{16.55} - 15.5 = 1.05'$  OK



Flood Depths 1.5 miles d/s



Approx. Section of Souhegan R.  
~1.5<sup>+</sup> miles d/s of Hillsboro Dam

A stream rating table based on the section sketched above is shown on the following page.

$Q_{\text{normal}} = 12070 \text{ cfs}$   
Flood depth  $\approx 10.6'$

Q dam break = 13500 cfs  
Flood depth = 11.1'

These flow depths appear consistent with FIS  
Flood Boundary - Work Maps

16/20

DEPTH	ELEV	AREA	WPER	HYD-R	AR2/3	Q
0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.5	0.5	35.9	73.7	0.5	22.2	45.3
1.0	1.0	73.5	77.4	1.0	71.1	145.1
1.5	1.5	113.0	81.0	1.4	141.0	287.6
2.0	2.0	154.2	84.7	1.8	229.8	468.9
2.5	2.5	197.1	88.4	2.2	336.6	686.7
3.0	3.0	241.9	92.1	2.6	460.6	939.8
3.5	3.5	291.7	99.0	2.8	562.4	1147.4
4.0	4.0	350.7	109.0	3.0	691.9	1411.7
4.5	4.5	416.7	126.0	3.5	850.8	1735.8
5.0	5.0	491.5	142.9	3.9	1040.3	2123.6
5.5	5.5	575.5	159.8	4.3	1264.3	2579.4
6.0	6.0	667.5	176.8	4.6	1523.1	3107.5
6.5	6.5	768.0	193.8	5.0	1819.5	3712.2
7.0	7.0	876.2	210.7	5.5	2155.2	4397.8
7.5	7.5	994.2	227.6	5.9	2533.7	5168.5
8.0	8.0	1120.0	244.6	6.3	2954.4	6028.4
8.5	8.5	1254.2	261.6	6.7	3421.9	6981.6
9.0	9.0	1396.9	278.5	7.0	3936.8	8032.0
9.5	9.5	1548.0	295.5	7.4	4501.4	9184.9
10.0	10.0	1707.5	312.4	7.8	5117.4	10440.8
10.5	10.5	1875.5	329.4	8.2	5786.9	11806.8
11.0	11.0	2051.7	346.3	8.6	6511.6	13285.4
11.5	11.5	2236.9	363.2	9.0	7293.3	14880.3
12.0	12.0	2430.9	380.2	9.4	8133.8	16595.1
12.5	12.5	2706.9	397.7	9.8	9099.3	18508.6
13.0	13.0	2992.5	564.3	10.1	9916.8	18192.6

STREAM RATING

SOUHEGAN RIVER

1.5 MILES D/S OF HILLSBOROUGH DAM

## Test Flood Analysis

Size Classification -- Small

Storage  $< 1000$  AF

Height  $< 40'$

Hazard Classification -- Low

- Dam failure will not damage railroad and highway bridges d/s.
- In vicinity of structures 1.5 miles d/s, flood levels would be increased only about 0.5' by dam failure.

## Test Flood Selection

Per COE guidelines, a small dam with Low hazard potential should use a 50-yr. to 100-yr. test flood. As the dam is located in a developed area, choose 100-yr. flood.

A 1978 FIS study by ANCO estimated 10, 50, 100, and 500 year discharges at the Hillsborough Mills Dam as follows:

Recurrence Interval	Peak Discharge
10 yr.	3740 cfs
50	6360
→ 100	<u>7550</u>
500	11000

Drainage Area = 97 sq. mi

See map on following page

$$Q_{100} = 7550 \text{ cfs}$$

$$= 7550/97 = 78 \text{ csm}$$

The discharges shown are somewhat low for a drainage area of this size. This might be explained by the fact that the watershed includes numerous ponds and reservoirs to detain runoff.

The 100-yr. discharge of 5700 cfs was computed at the dam, so that storage routing through the reservoir need not be considered. In any case, the surcharge storage available is too small to have significant effect. For these reasons, a stage-storage function has not been calculated.

### Test Flood Summary

Size -- small

Hazard -- low

Test Flood -- use 100 yr. peak

$Q_{100} = 7550$  cfs (FLS)

Head on spillway = 6.8' (Dam Rating)

There will be overtopping flows with a max. depth of 2.8' around the gate house at the left abutment under test flood conditions.

With 4' flashboards in place and intact under flood conditions, the Test Flood would reach a stage greater than 9' above the spillway crest and the railroad embankment along the left bank of the Souhegan R. upstream of the dam would be overtopped. The extent and depth of overtopping is unknown.

APPENDIX E  
INFORMATION AS CONTAINED IN  
THE NATIONAL INVENTORY OF DAMS

**END**

**FILMED**

**8-85**

**DTIC**